Updates on Operational Processing of ATMS TDR and SDR Products

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Outline

- ATMS Instrument Characterization
- ATMS in-orbit Performance Status
- Advanced ATMS SDR Sciences and Algorithms
- Upcoming Changes in ATMS TDR/SDR Processing
- Summary and Conclusions

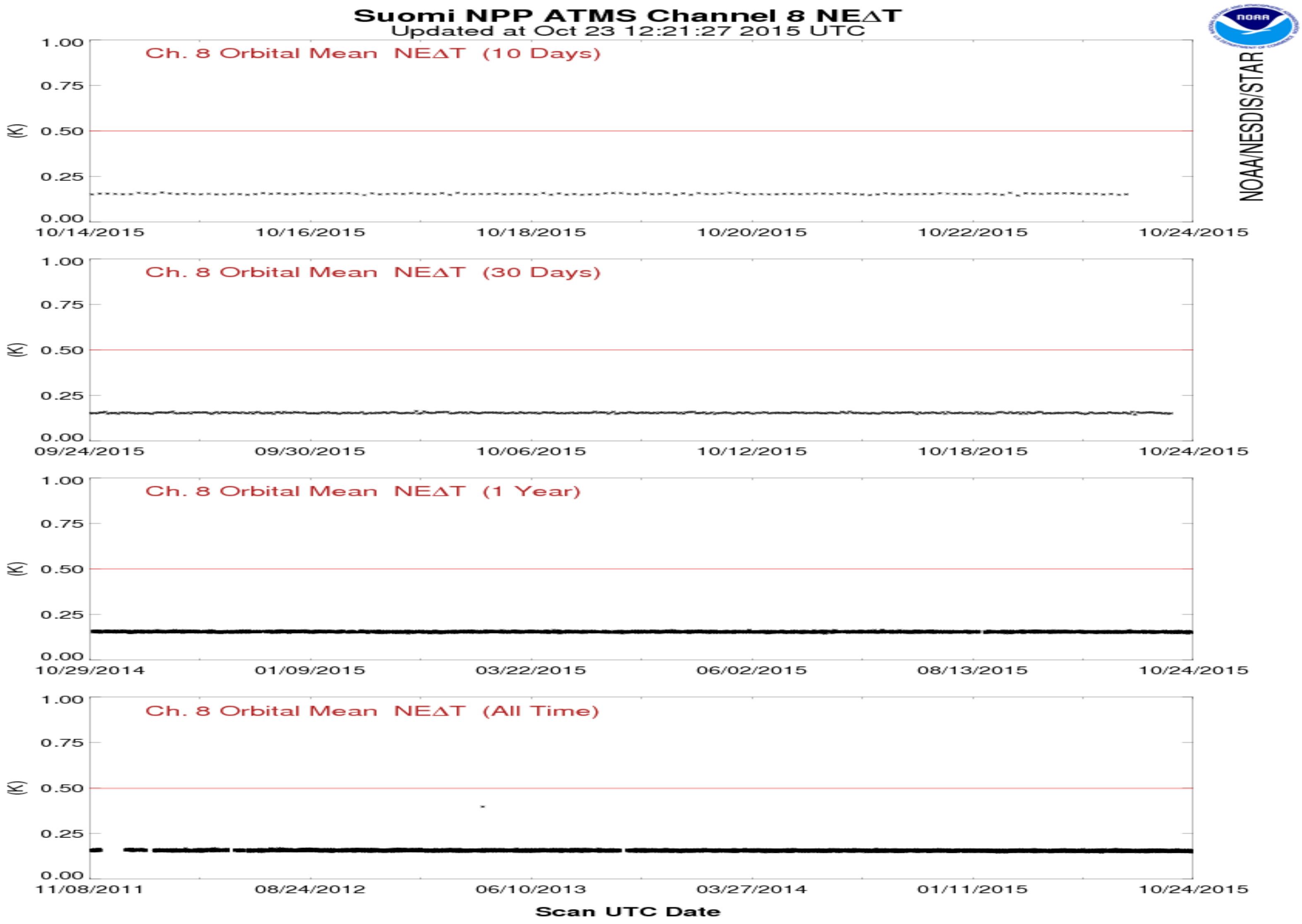
MSU			AMSU/MHS			ATMS		
Ch	GHz	Pol	Ch	GHz	Pol	Ch	GHz	Pol
			1	23.8	QV	1	23.8	QV
			2	31.399	QV	2	31.4	QV
1	50.299	QV	3	50.299	QV	3	50.3	QH
						4	51.76	QH
			4	52.8	QV	5	52.8	QH
2	53.74	QH	5	53.595 ± 0.115	QH	6	53.596 ± 0.115	QH
			6	54.4	QH	7	54.4	QH
3	54.96	QH	7	54.94	QV	8	54.94	QH
			8	55.5	QH	9	55.5	QH
4	57.95	QH	9	fo = 57.29	QH	10	fo = 57.29	QH
			10	fo ± 0.217	QH	11	fo±0.3222±0.217	QH
			11	fo±0.3222±0.048	QH	12	fo± 0.3222±0.048	QH
			12	fo ±0.3222±0.022	QH	13	fo±0.3222±0.022	QH
			13	fo± 0.3222±0.010	QH	14	fo±0.3222 ±0.010	QH
			14	fo±0.3222±0.0045	QH	15	fo± 0.3222±0.0045	QH
			15	89.0	QV			
			16	89.0	QV	16	88.2	QV
			17	157.0	QV	17	165.5	QH
						18	183.31 ± 7	QH
						19	183.31 ± 4.5	QH
			19	183.31 ± 3	QH	20	183.31 ± 3	QH
			20	191.31	QV	21	183.31 ± 1.8	QH
			18	183.31 ± 1	QH	22	183.31 ± 1	QH

- Exact match to AMSU/MHS (green)
- Only Polarization different (yellow)
- Unique Passband (orange)
- Unique Passband, and Pol. different from closest AMSU/MHS channels (red)

SNPP ATMS in-orbit Performance

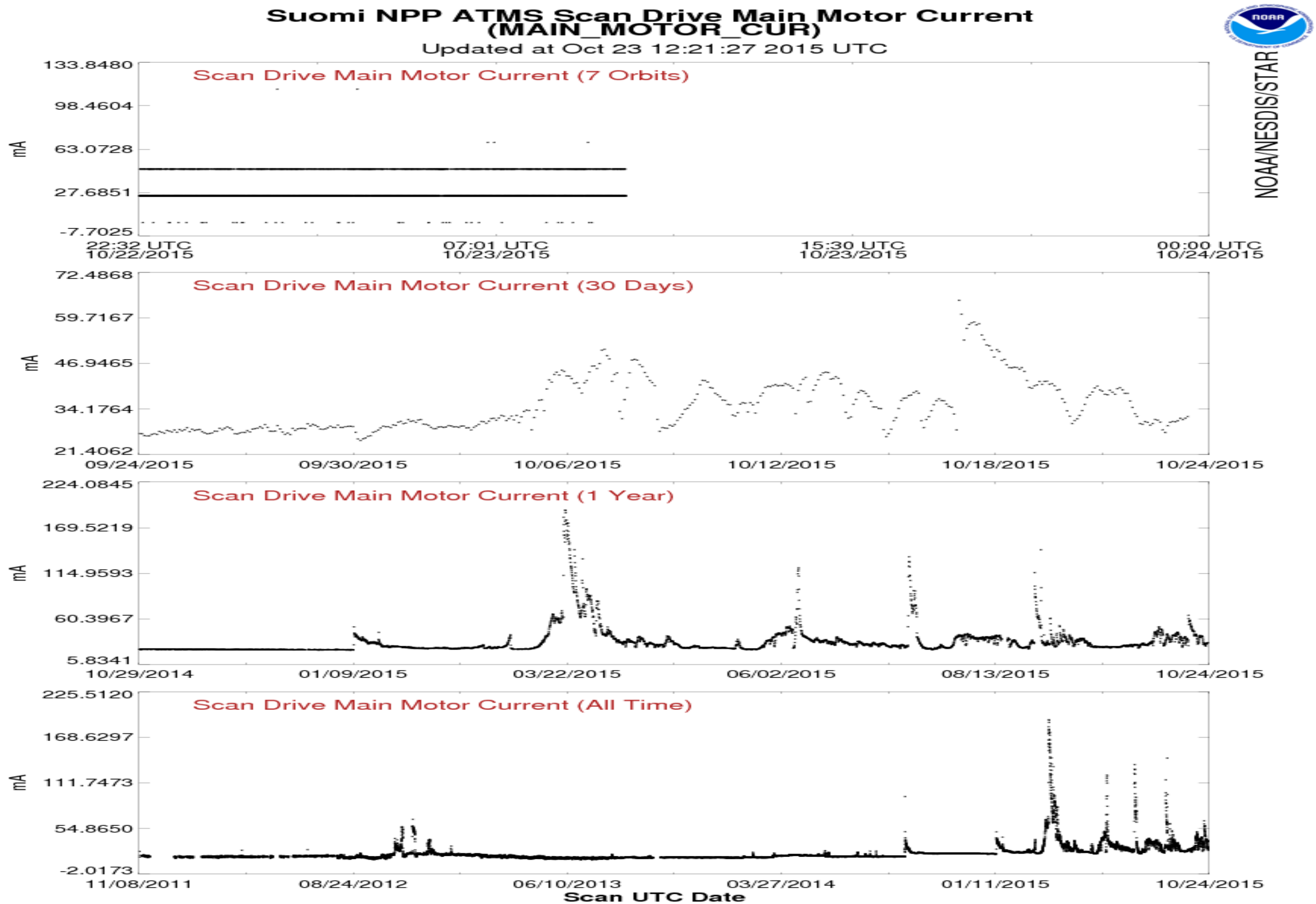
- Stable instrument noise and calibration gain since its launch on October 28, 2011
- Several major anomalies occurred in scan motor current (>120 mA) with its magnitude well below the threshold
- Starting on August 23, 2015, a periodical spike has been observed in scan motor current due to executions of daily scan reversal
- TDR/SDR data quality is affected by scan motor current spikes and anomalies

ATMS Noise Equivalent Differential Temperature (NEDT) Derived from Allan Variance



NEDT for other channels can be viewed from http://www.star.nesdis.noaa.gov/icvs/

ATMS Scan Drive Main Motor Current Monitoring



Scientific Advances in ATMS SDR Algorithm

- Standardized NEdT calculation for ATMS and other microwave sounding instruments using Allan deviation. The new algorithm has resulted in much stable noise trending

- Developed and implemented a physical model for correcting the lunar emission in cold calibration count

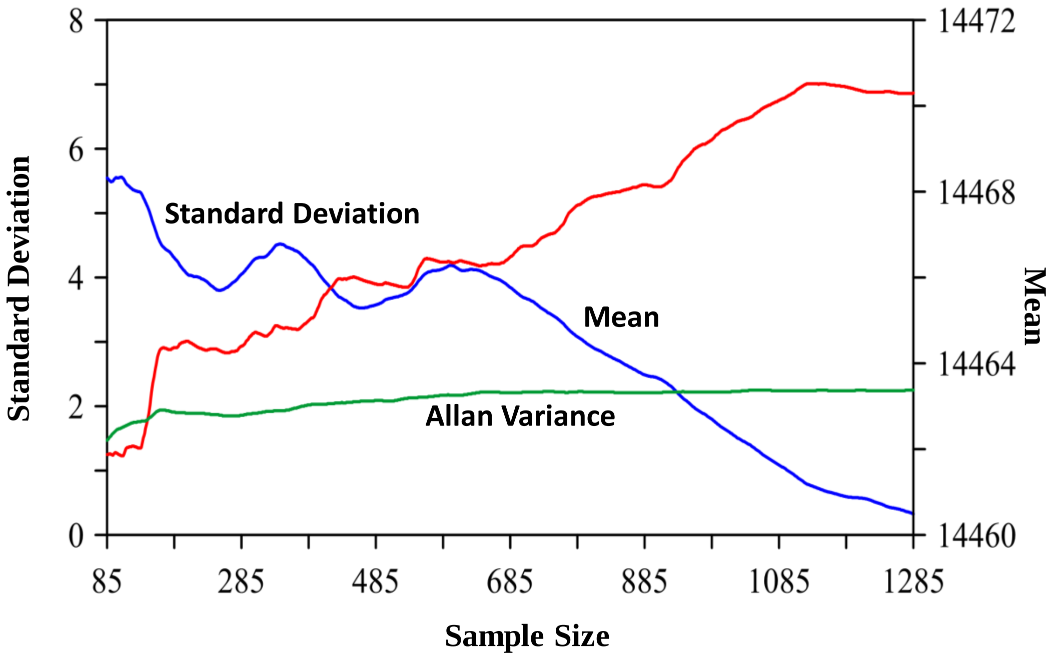
- Optimized the ATMS de-striping algorithm for the earth scene brightness temperatures and generated a dataset for NWP user community to assess impacts of ATMS de-striped data on forecast skills

- Updated the quality flags related to spacecraft maneuvers and scan reversals in TDR and SDR datasets

ATMS Noise Equivalent Temperature (NEDT)

For a time series with a stable mean, the standard deviation of the measurements can be used as NEDT:

$$\sigma_{ch} = \left[\frac{1}{4N} \sum_{i=1}^{N} \sum_{j=1}^{4} \left(\frac{C_{ch}^{w}(i,j) - \overline{C_{ch}^{w}(i)}}{\overline{G_{ch}(i)}} \right)^2 \right]^{1/2}$$



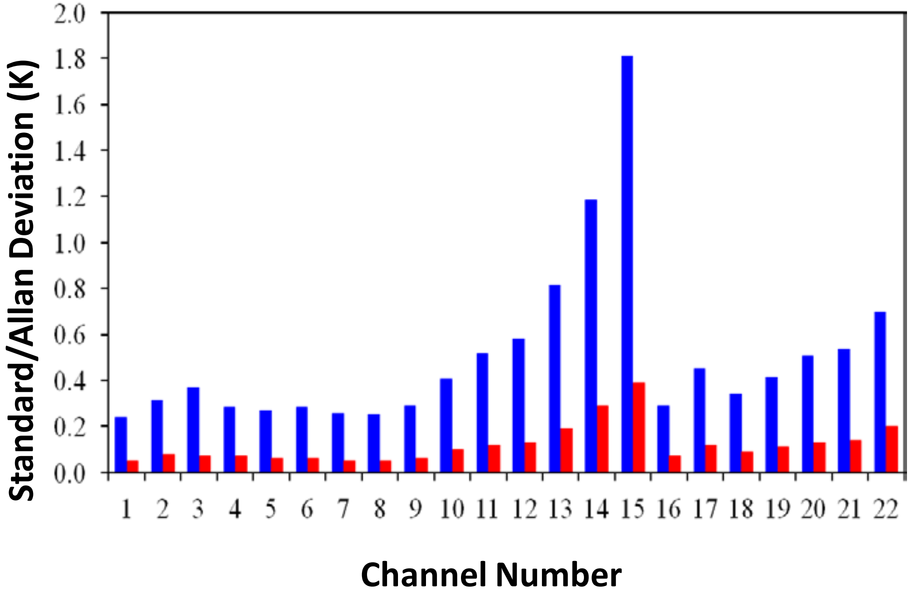
For a non-steady mean such as ATMS warm count from blackbody target, Allan variance works the best for NEDT:

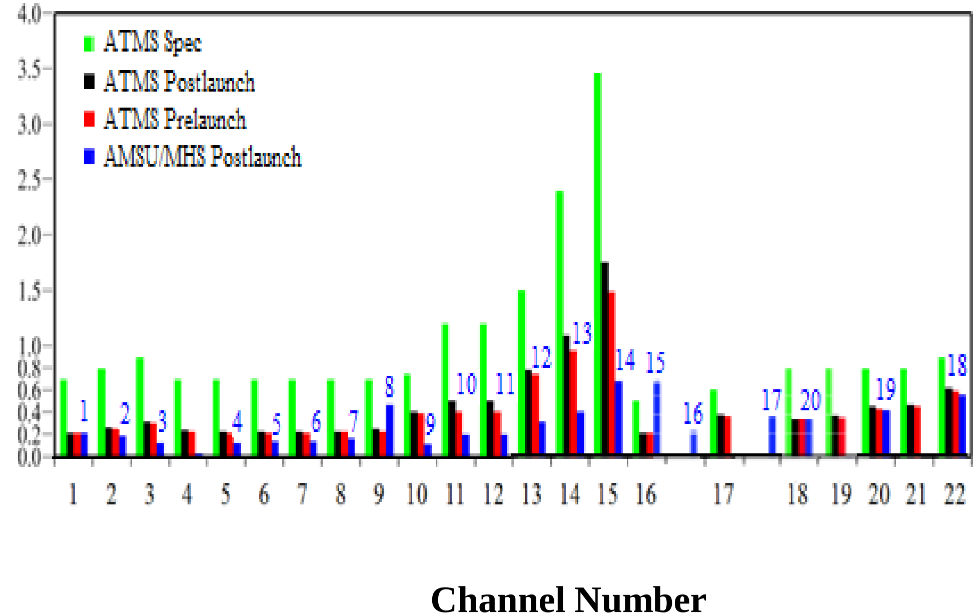
$$\sigma^{Allan}(m) = \sqrt{\frac{1}{2m^2(N-2m)} \sum_{j=1}^{N-2m} \left(\sum_{i=j}^{j+m-1} \left(C_{ch}^{w}(i+m) - C_{ch}^{w}(i) \right) \right)^2}$$

ATMS channel 1 warm count mean (blue, y-axis on the right), the standard deviation (red, y-axis on the left) and the overlapping Allan deviation (green, y-axis on the left) of the 17-scanline (m) average as a function of the total sample size (N).

M. Tian, X. Zou and F. Weng, "*Use of Allan Deviation for Characterizing Satellite Microwave Sounders Noise Equivalent Differential Temperature (NEDT)*", IEEE Geosci. Remote Sens. Lett., Digital Object Identifier 10.1109/LGRS.2015.2485945

ATMS Noise Equivalent Temperature (NEDT)





ATMS standard deviation (blue) and Allan deviation (red) with channel number. The sample size (N) is 150 and the averaging factor (m) for the warm counts is 17. The standard deviation is much higher than Allan deviation.

On-orbit ATMS noise from the standard deviation is lower than specification but is higher than AMSU/MHS. ATMS resample algorithm can further reduce the noise comparable to AMSU/MHS

ATMS Lunar Intrusion Correction Algorithm

Brightness temperature increment arising from lunar contamination can be expressed as a function of lunar solid angle, antenna response and radiation from the Moon

Space view Tb or radiance increment:

$$\Delta T_{moon} = G * \Omega * T_{moon}$$

Antenna response function:

$$G = e^{\frac{-(\beta' - \alpha_0)^2}{2\delta^2}}, \quad with\ \delta = \frac{0.5 \cdot \theta_{3dB}}{\sqrt{2 \cdot log2}}$$

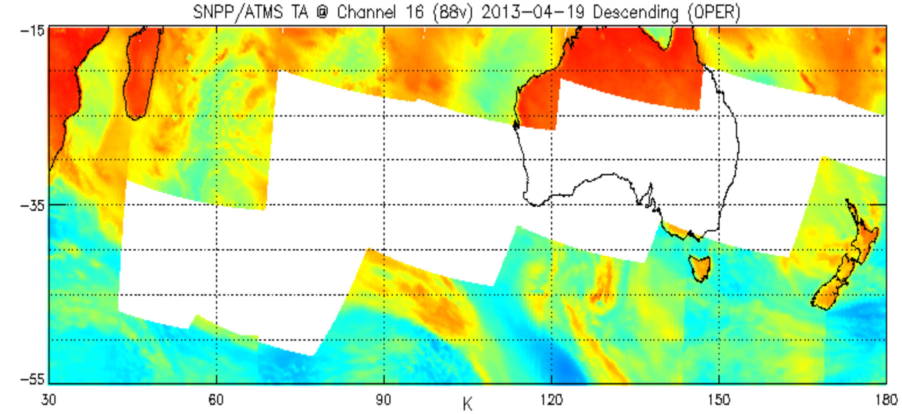
Weights of the Moon in antenna pattern:

$$\Omega_{moon} = \frac{\pi\left(\frac{r_{moon}}{D_{moon}}\right)^2}{\iint G(\theta,\varphi)d\theta d\varphi}$$

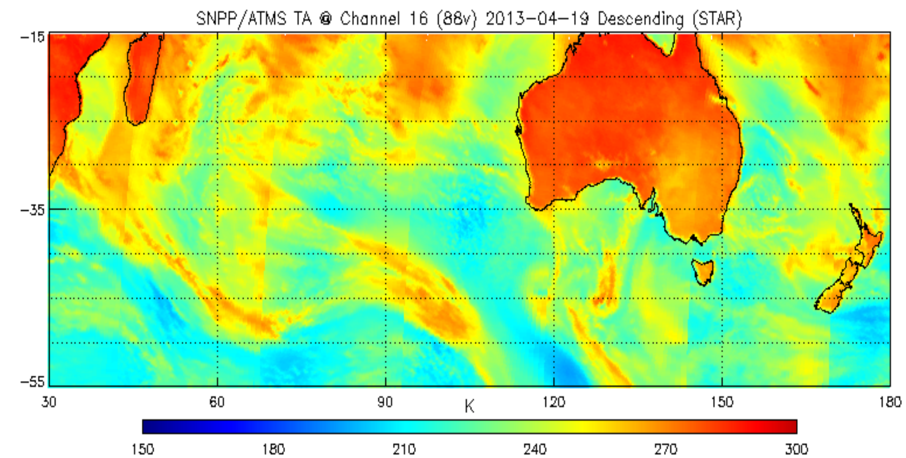
Brightness temperature of the Moon:

$$T_{moon} = 95.21 + 104.63 \cdot (1 - cos\Theta) + 11.62 \cdot (1 + cos2\Theta)$$

Without LI correction



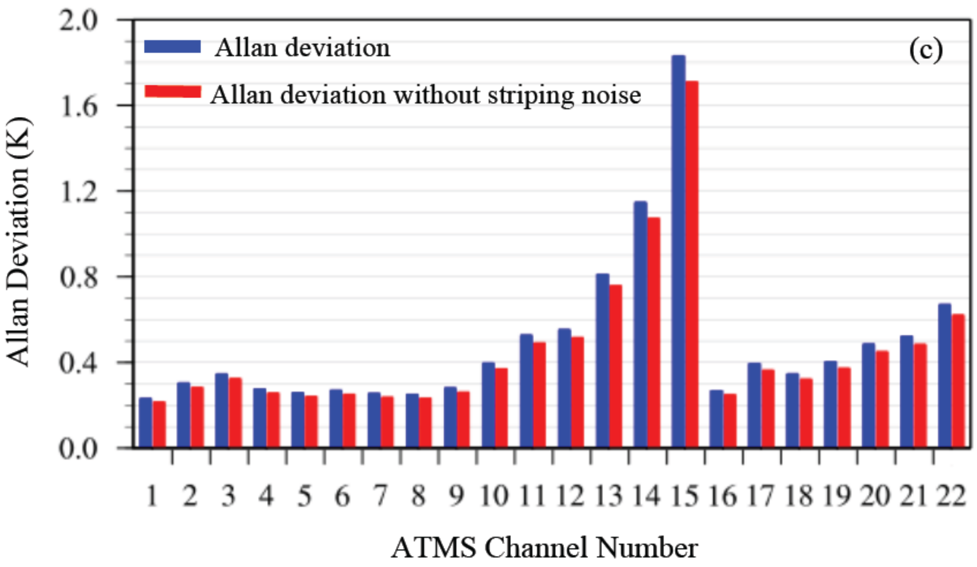
With LI correction



Impacts of ATMS Striping Effects on Channel Noise Characterization

Channel	NEDT (K)		Allan Deviation (K)	
	Before	After	Before	After
1	0.3490	0.3256	0.2324	0.2171
2	0.3977	0.3593	0.3052	0.2843
3	0.3945	0.3464	0.3473	0.3248
4	0.3279	0.2883	0.2772	0.2581
5	0.3232	0.2871	0.2603	0.2422
6	0.3433	0.3069	0.2714	0.2526
7	0.3518	0.3201	0.2559	0.2382
8	0.3453	0.3138	0.2518	0.2345
9	0.3421	0.3046	0.2816	0.2628
10	0.4542	0.3968	0.3981	0.3716
11	0.5675	0.4900	0.5277	0.4922
12	0.6140	0.5365	0.5534	0.5174
13	0.8718	0.7527	0.8123	0.7593
14	1.1849	1.0179	1.1479	1.0727
15	1.8476	1.5651	1.8319	1.7110
16	0.3914	0.3578	0.2692	0.2501
17	0.9237	0.8865	0.3954	0.3650
18	0.5496	0.5103	0.3479	0.3230
19	0.6637	0.6149	0.4041	0.3740
20	0.7636	0.7039	0.4859	0.4508
21	0.8862	0.8202	0.5239	0.4848
22	1.1194	1.0337	0.6712	0.6217

- Channel noise reduced after applying striping mitigation algorithm
- 45-day de-striping BUFR data generated for NWP impact study



Qin, Z., X. Zou and F. Weng, 2013: Analysis of ATMS and AMSU striping noise from their earth scene observations. J. Geophy. Res., 118, 13,214-13,229, doi: 10.1002/ 2013JD020399

Ma, Y. and X. Zou, 2015: Optimal filters for striping noise mitigation within ATMS calibration counts. IEEE Trans. Geo. Remote Sensing, (in revision)

Upcoming Changes in ATMS SDR Processing

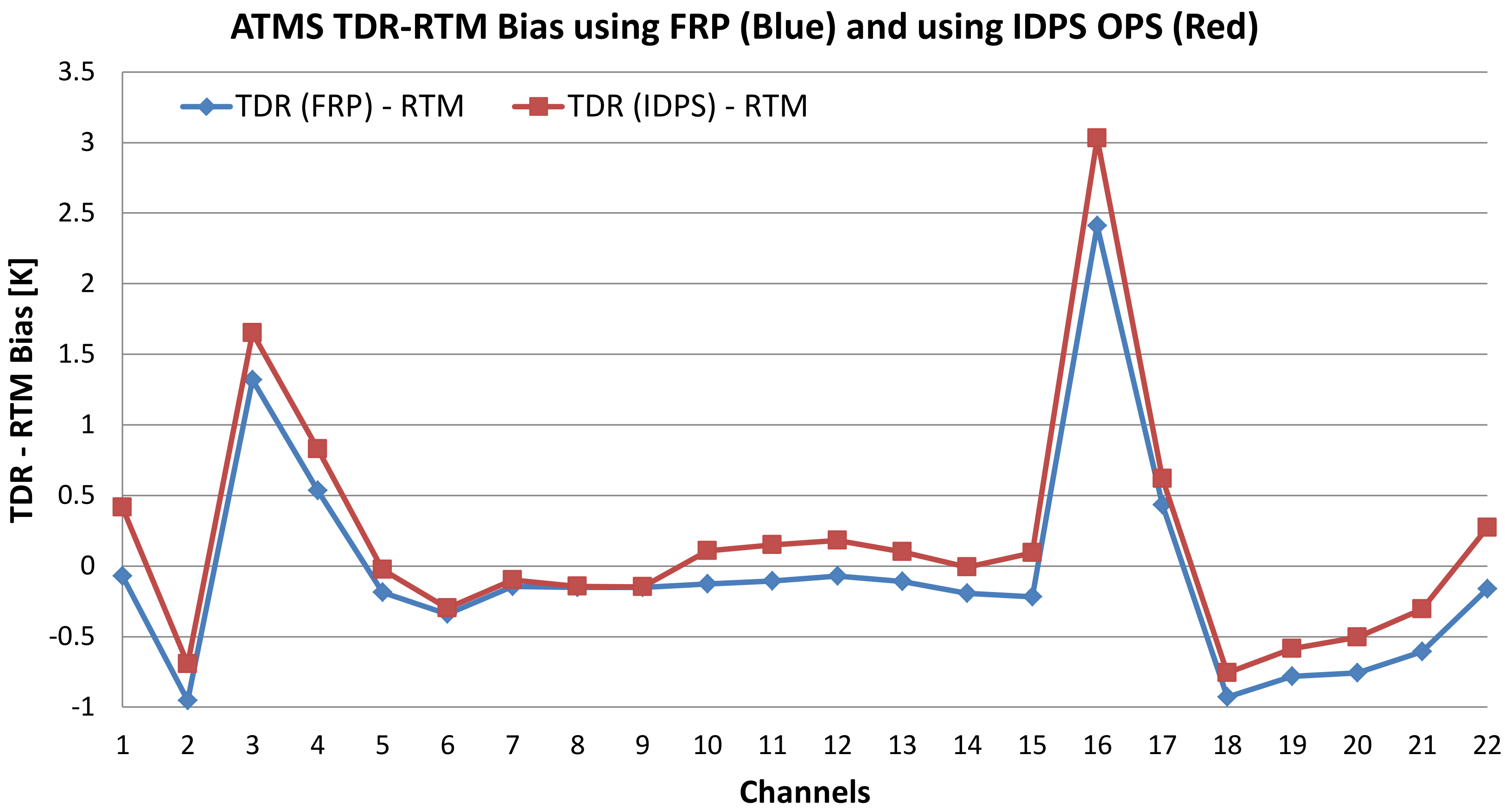
1. SNPP ATMS nonlinearity calibration term was implemented incorrectly in the early IDPS processing and its sign to the linear term needs to be reversed

2. A radiometric two-point calibration in radiance has been developed and the full radiance calibration algorithm will be implemented in IDPS Block 2.0 or ADL5.3(direct readout users)

3. A physical model has been developed and will be implemented for correcting the emitted radiation from ATMS flat reflector

4. SNPP ATMS RDR data will be reprocessed with the latest IDPS version to generate a climate quality of TDR and SDR products

Global Mean O-B Bias from ATMS Full Radiance Calibration



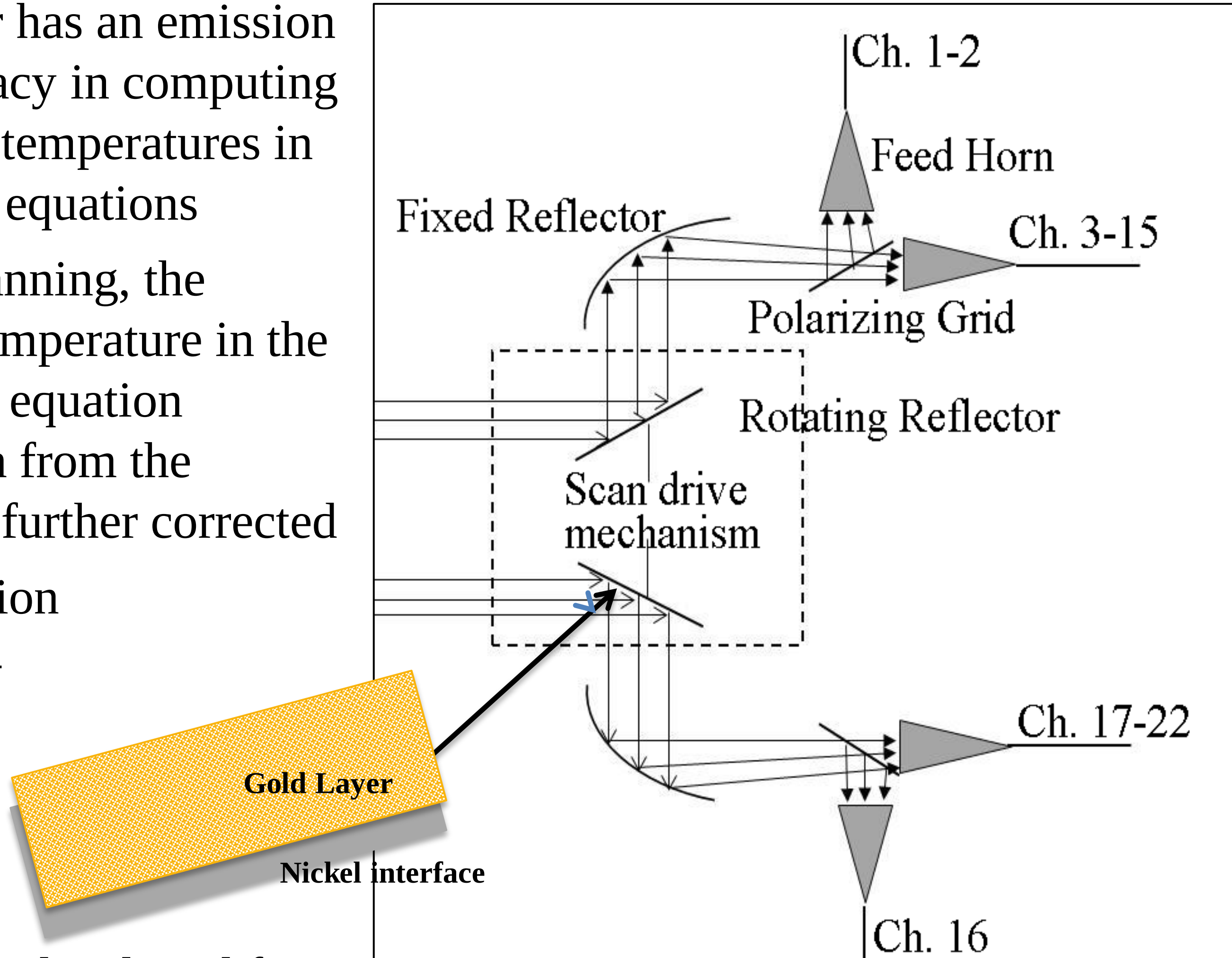
ATMS full radiance calibration (FRC) performs two corrections: 1) replacing the brightness temperatures (R-J approximation) with Plank function radiance and 2) reversing the sign in nonlinearity term. WG bands are affected by two corrections where other channels are mainly affected by the nonlinearity term.

ATMS Reflector Emission and Its Effects on TDR

- Flat rotating reflector has an emission and affects the accuracy in computing the calibration target temperatures in two point calibration equations
- In the earth scene scanning, the antenna brightness temperature in the two-point calibration equation contains the emission from the antenna that must be further corrected
- Hagen-Rubens equation

$$\varepsilon_N = \sqrt{16\pi e_0 f / \sigma}$$

0.0025 to 0.0065



- An algorithm is being developed for ATMS TDR correction

Effects of ATMS Flat Reflector Emission on Brightness Temperature

Quasi-V (TDR) :

$$R_{qv}^{c} = R_{qv} + \varepsilon_h (R_r - R_h) + [\varepsilon_v (R_r - R_v) - \varepsilon_h (R_r - R_h)]\sin^2\theta - \frac{R_3}{2}(1-\varepsilon_h)^{3/2} sin2\theta$$

Quasi-H (TDR):

Bias due to the reflector emission

$$R_{qh}^{c} = R_{qh} + \varepsilon_h (R_r - R_h) + [\varepsilon_v (R_r - R_v) - \varepsilon_h (R_r - R_h)]\cos^2\theta + \frac{R_3}{2}(1-\varepsilon_h)^{3/2} \sin 2\theta$$

where

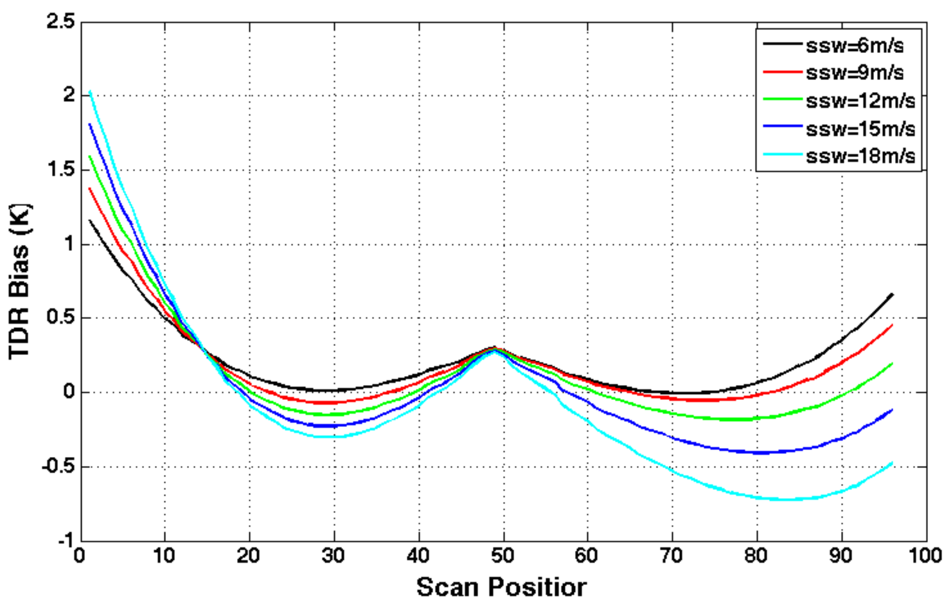
R_{qv} and R_{qh} are the radiances at quasi vertical and horizontal polarzation which are further related to the radiances at pure vertical and horizontal polarization, R_v and R_h. ε_v and ε_h are the reflector emissivity at the vertical and horizontal polarization. R_3 is the third Stokes radiance component of the scene. R_r is the radiance emitted from the reflector. θ is the scan angle. Note that $\varepsilon_v = 2\varepsilon_h - \varepsilon_h^2$ at an indent angle of 45 degree to reflector normal.

Yang, H. and F. Weng, 2015: Estimation of ATMS Antenna Emission from cold space observations, IEEE Geosci. Trans. Remote. Sens, in press

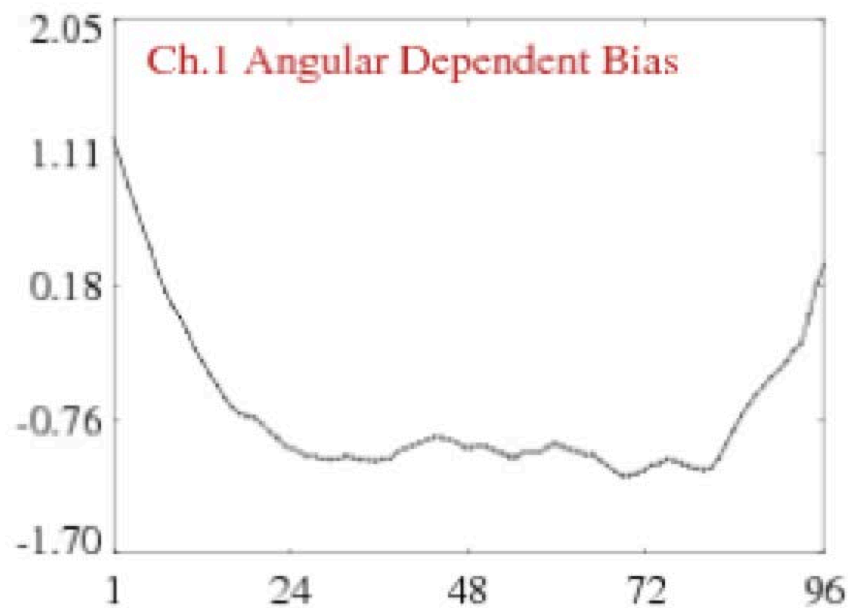
The Reflector-Emission Bias at Earth Views

ATMS channel-1 (23.8 GHz, QV polarization) scan position dependent TDR Bias

Simulated (Under different SSW conditions)

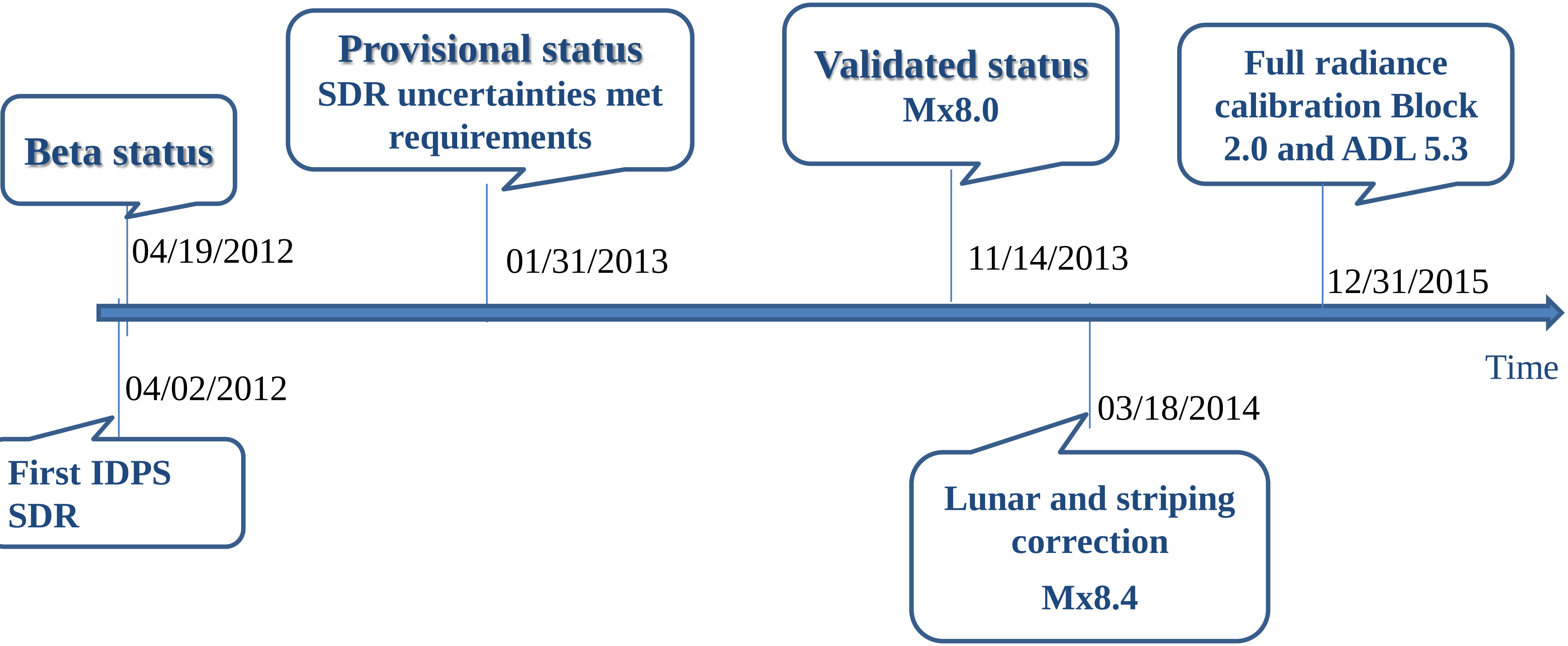


O(TDR)-B(CRTM simulation)



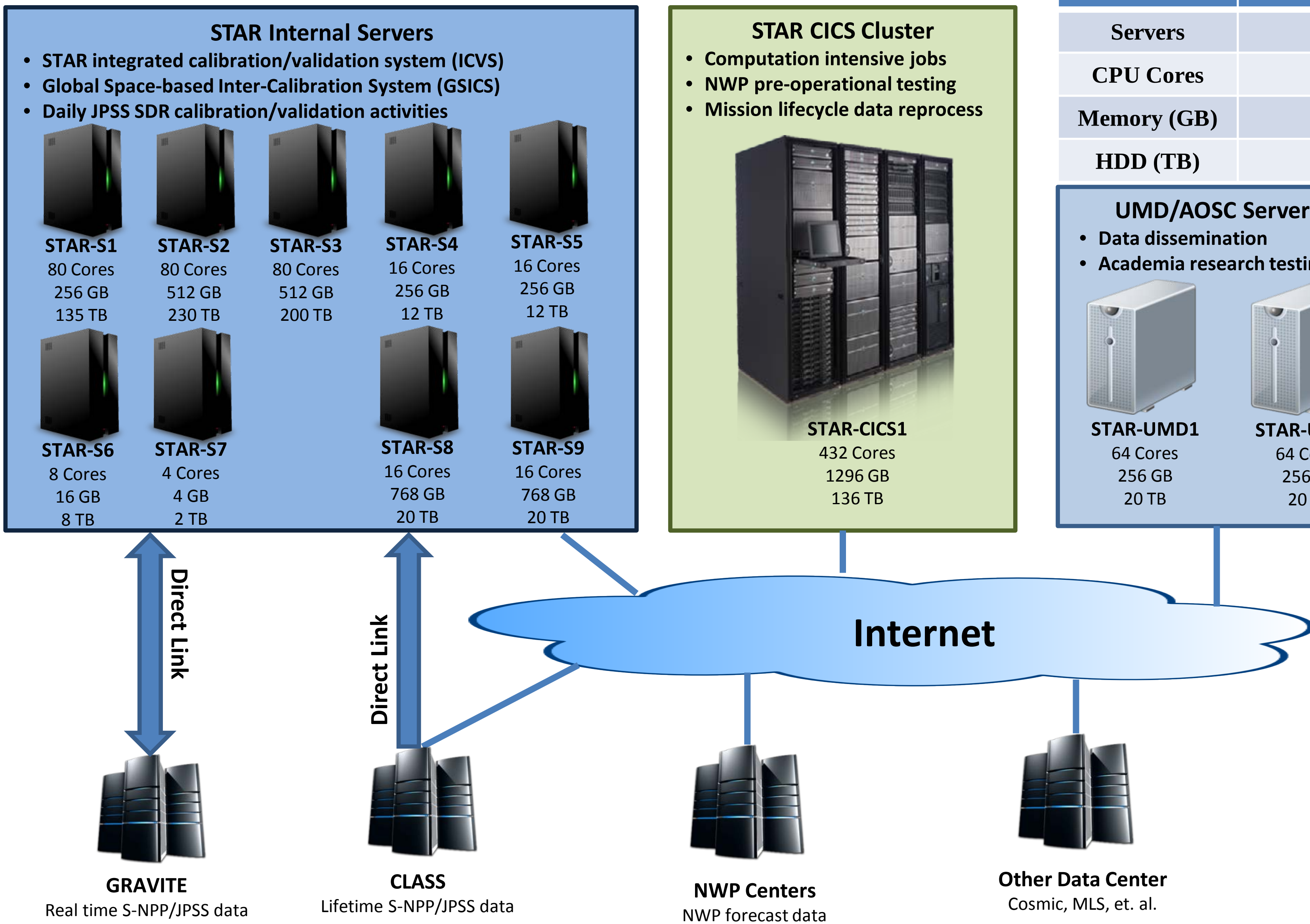
- For polarized scene, the impact of reflector emission is dependent on the temperature difference between antenna reflector and V-pol scene
- The scan angle dependent feature in the error is mainly dominated by the third Stokes component of the scene radiation.
- The simulated scan bias in TDR is consistent with those in real observations

SNPP ATMS SDR CalVal Major Milestones

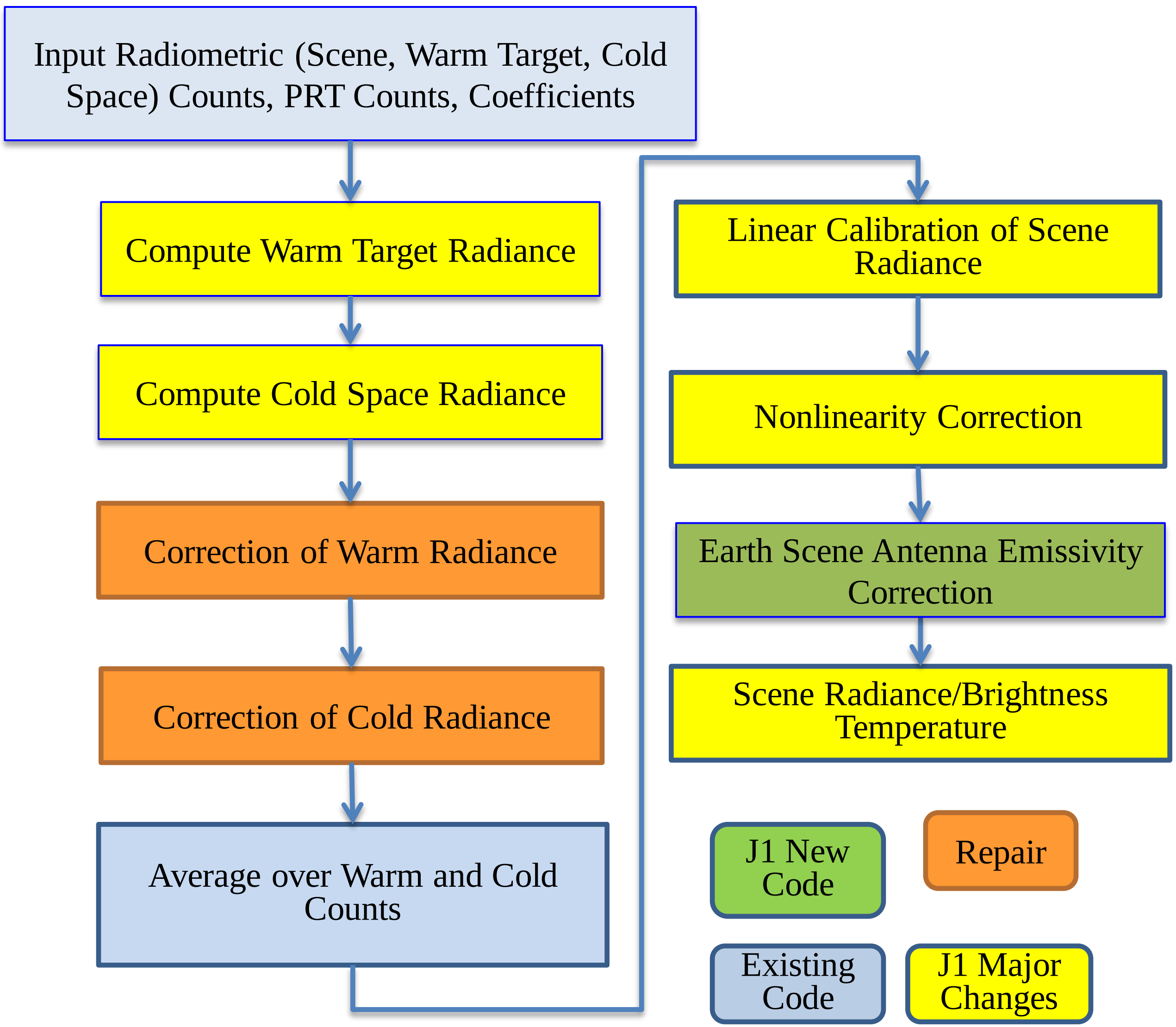


STAR SDR Testbed for JPSS Reprocessing

Parts	Total
Servers	12
CPU Cores	876
Memory (GB)	5156
HDD (TB)	815



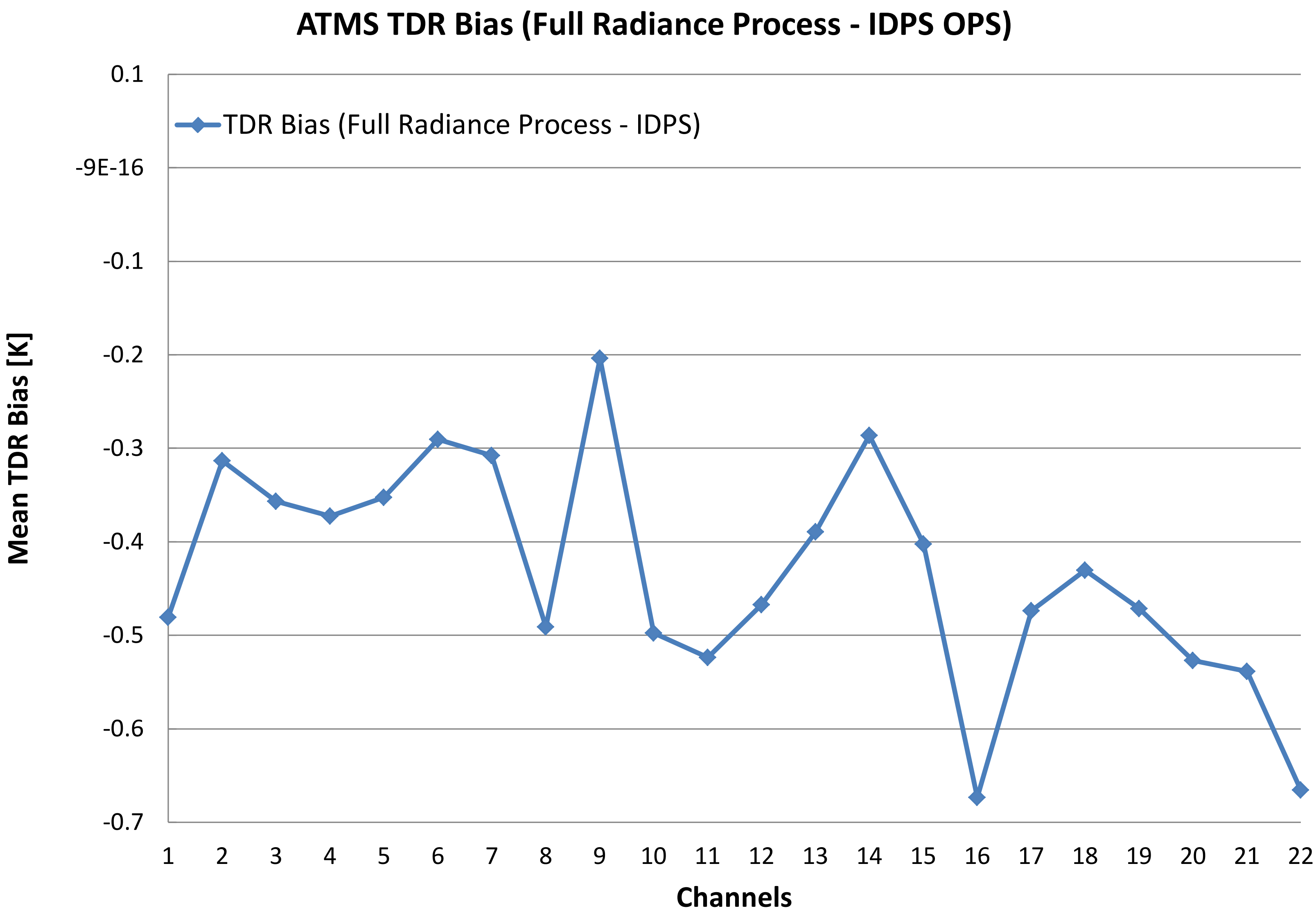
ATMS SDR Algorithm Change from SNPP to JPSS



Major Changes:

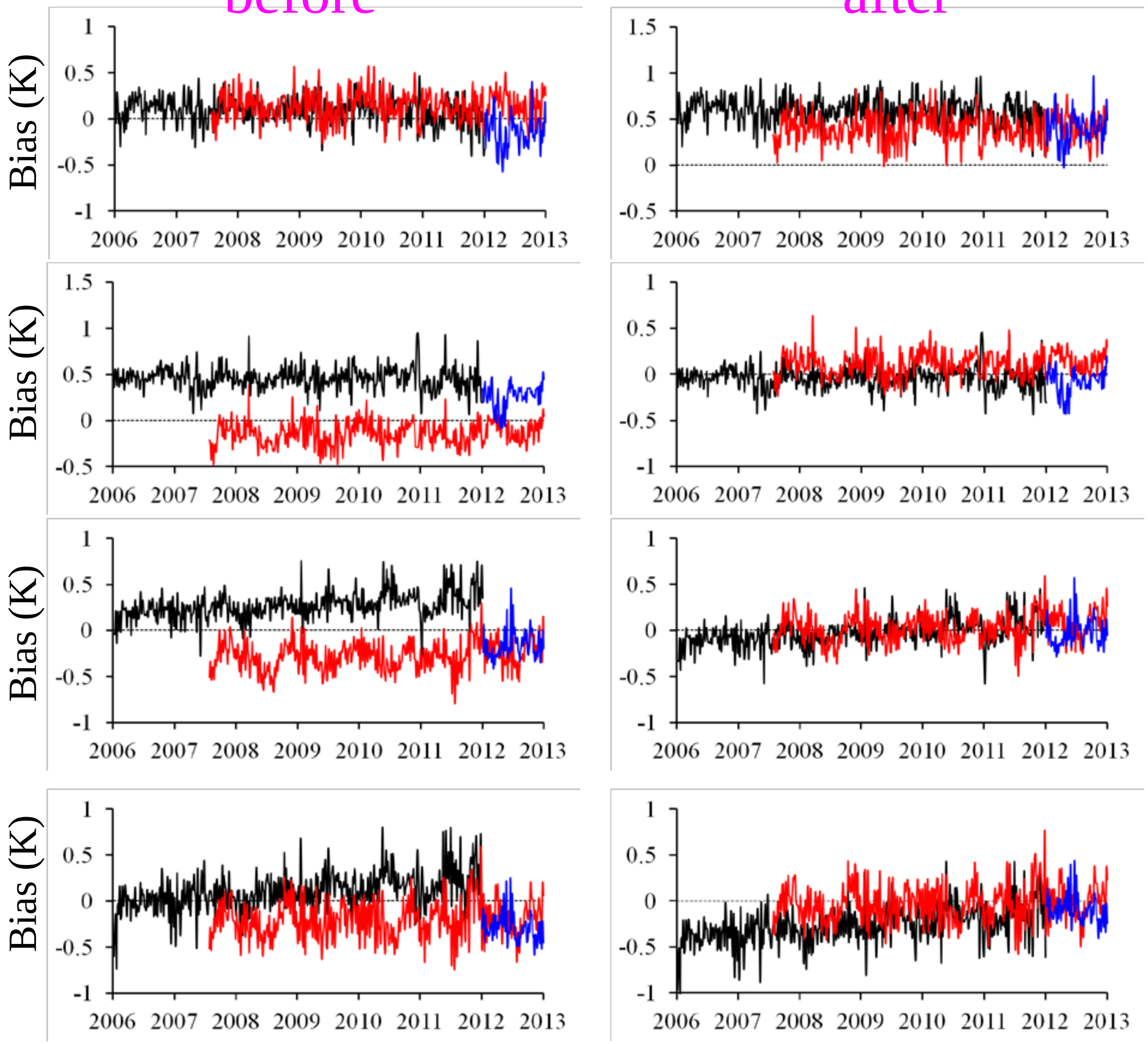
- Radiance based calibration
- Model based lunar contamination correction
- Updated parameterized nonlinearity correction
- Model based antenna reflector emissivity correction

Global Mean TDR Bias



Biases in the Tropics (NOAA-15, MetOp-A, SNPP)

before after



ATMS channel 10

ATMS channel 11

ATMS channel 13

ATMS channel 14

NOAA-18 is subtracted. The pentad data set within ±30^{o} latitudinal band.

Summary and Conclusions

- ATMS on-orbit NEDT is well characterized by new Allan deviation method, resulting in much lower NEDT values
- ATMS scan motor has been commanded for one reversal every 14 orbits for the purpose of extending its design life beyond 5 years
- ATMS full radiance calibration algorithm has been developed and will be implemented into IDPS Block 2.0
- ATMS flat reflector emission is fully characterized by using a physical model and pitch-over maneuver data. The algorithm for correcting this emission is ready for implementation into IDPS processing system
- ATMS O-B bias can be fully characterized if a full polarimetric RT model is used in simulation. The third Stokes component contributes to the simulated radiance in quasi-V and quasi-H channels
- J1 ATMS went through rework and V-band IF receiver and WG band video components were replaced with new parts. ATMS SDR science team is currently analyzing the TVAC data